



Designation: D4582 – 05

Standard Practice for Calculation and Adjustment of the Stiff and Davis Stability Index for Reverse Osmosis¹

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1. Scope

1.1 This practice covers the calculation and adjustment of the Stiff and Davis Stability Index (S & DSI) for the concentrate stream of a reverse osmosis device. This index is used to determine the need for calcium carbonate scale control in the operation and design of reverse osmosis installations. This practice is applicable for concentrate streams containing more than 10 000 mg/L of total dissolved solids. For concentrate streams containing less than 10 000 mg/L of total dissolved solids, refer to Practice D3739.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- D511 Test Methods for Calcium and Magnesium In Water
- D1067 Test Methods for Acidity or Alkalinity of Water
- D1129 Terminology Relating to Water
- D1293 Test Methods for pH of Water
- D1888 Test Methods for Particulate and Dissolved Matter in Water³
- D3739 Practice for Calculation and Adjustment of the Langelier Saturation Index for Reverse Osmosis
- D4194 Test Methods for Operating Characteristics of Reverse Osmosis and Nanofiltration Devices
- D4195 Guide for Water Analysis for Reverse Osmosis and Nanofiltration Application

¹ This practice is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.08 on Membranes and Ion Exchange Materials.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Withdrawn.

D6161 Terminology Used for Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis Membrane Processes

3. Terminology

3.1 *Definitions*—For definitions of terms used in the practice, refer to Terminology D1129 and D6161.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 For description of terms relating to reverse osmosis, refer to Test Methods D4194.

3.2.2 *Stiff and Davis Stability Index (S & DSI)*⁴—an index calculated from total dissolved solids, calcium concentration, total alkalinity, pH, and solution temperature that shows the tendency of a water solution to precipitate or dissolve calcium carbonate.

4. Summary of Practice

4.1 This practice consists of calculating the S & DSI index for a reverse osmosis concentrate stream from the total dissolved solids, calcium ion content, total alkalinity, pH, and temperature of the feed solution and the recovery of the reverse osmosis system.

4.2 This practice also presents techniques to lower the S & DSI by decreasing the recovery; decreasing the calcium and alkalinity concentrations; or by changing the ratio of total alkalinity to free carbon dioxide in the feedwater.

5. Significance and Use

5.1 In the design and operation of reverse osmosis installations, it is important to predict the calcium carbonate scaling properties of the concentrate stream. Because of the increase in total dissolved solids in the concentrate stream and the differences in salt passages for calcium ion, bicarbonate ion, and free CO₂, the calcium carbonate scaling properties of the concentrate stream will generally be quite different from those of the feed solution. This practice permits the calculation of the S & DSI for the concentrate stream from the feed water analyses and the reverse osmosis operating parameters.

⁴ Stiff, H. A. and Davis, L. E., "A Method for Predicting the Tendency of Oil Field Waters to Deposit Calcium Carbonate," *Petroleum Transactions*, Vol 195, 1952.

5.2 A positive S & DSI indicates the tendency to form a calcium carbonate scale, which can be damaging to reverse osmosis performance. This practice gives procedures for the adjustment of the S & DSI.

6. Procedure

6.1 Determine the calcium concentration in the feed solution in accordance with Test Methods **D511** and express as CaCO_3 as demonstrated in section **6.6**.

6.2 Determine the total dissolved solids of the feed solution using Test Methods **D1888**.

6.3 Determine the total alkalinity of the feed solution using Test Methods **D1067** and express as CaCO_3 .

6.4 Measure the pH of the feed solution using Test Methods **D1293**.

6.5 Measure the temperature of the feed solution.

6.6 Convert feed water alkalinity and calcium as mg/L CaCO_3 .

$$Ca_f = [Ca^{+2}] \times \frac{100gCaCO_3}{mol} \times \frac{1000mg}{g} \times \frac{1eqCaCO_3}{1eqCa^{+2}} \quad (1)$$

$$Alk_f = [HCO_3^-] \times \frac{100gCaCO_3}{mol} \times \frac{1000mg}{g} \times \frac{1eqCaCO_3}{2eqHCO_3^-} \quad (2)$$

where:

where:

Ca_c = calcium concentration in concentrate as CaCO_3 , mg/L,

Ca_f = calcium concentration in feed as CaCO_3 , mg/L,

Alk_c = alkalinity in concentrate as CaCO_3 , mg/L, and

Alk_f = alkalinity in feed as CaCO_3 , mg/L.

6.7 Measure the concentration of all major ions using the methods cited in Guide **D4195**. At a minimum, measure the concentration of Mg^{++} , Na^+ , K^+ , SO_4^{--} , and Cl^- .

7. Calculation

7.1 Calculate the calcium concentration in the concentrate stream from the calcium concentration in the feed solution, the recovery of the reverse osmosis system, and the calcium ion passage as follows:

$$Ca_c = Ca_f \times \left(\frac{1 - Y(SP_{Ca})}{1 - Y} \right) \quad (3)$$

where:

Ca_c = calcium concentration in concentrate as CaCO_3 , mg/L,

Ca_f = calcium concentration in feed as CaCO_3 , mg/L,

Y = recovery of the reverse osmosis system, expressed as a decimal, and

SP_{Ca} = calcium ion passage, expressed as a decimal.

NOTE 1— SP_{Ca} can be obtained from the supplier of the specific reverse osmosis system. For most reverse osmosis devices, SP_{Ca} can be considered to be zero, in which case the equation simplifies to:

$$Ca_c = Ca_f \times \left(\frac{1}{1 - Y} \right) \quad (4)$$

This assumption will introduce only a small error.

7.2 Calculate the alkalinity in the concentrate stream from the alkalinity in the feed solution, the recovery of the reverse osmosis system, and the passage of alkalinity by:

$$Alk_c = Alk_f \times \frac{1 - Y(SP_{Alk})}{1 - Y} \quad (5)$$

where:

Alk_c = alkalinity in concentrate as CaCO_3 , mg/L,

Alk_f = alkalinity in feed as CaCO_3 , mg/L,

Y = recovery of the reverse osmosis system, expressed as a decimal, and

SP_{Alk} = alkalinity passage, expressed as a decimal.

NOTE 2— SP_{Alk} may be dependent on the pH of the feed solution, and its value should be obtained from the supplier of the specific reverse osmosis system.

7.3 Calculate the ionic strength of the feed stream by:

$$I_f = 1 / 2 \sum m_i z_i^2 \quad (6)$$

where:

I_f = ionic strength of the feed stream,

m_i = molal concentration of ion, i (moles/1000 g of water) in the feed solution, and

z_i = ionic charge of ion, i .

To calculate I_f use at least all major ions: Ca^{++} , Mg^{++} , Na^+ , K^+ , HCO_3^- , SO_4^{--} , and Cl^- .

7.4 Calculate the ion strength of the concentrate stream from the ionic strength of the feed solution, the recovery, and the total dissolved solids of the feed solution by:

$$I_c = I_f \left[\frac{10^6 - \text{TDS}_f}{10^6 - (\text{TDS}_f) \left(\frac{1}{1 - Y} \right)} \right] \left[\frac{1}{1 - Y} \right] \quad (7)$$

where:

I_c = ionic strength of the concentrate stream and

TDS_f = total dissolved solids of the feed solution, mg/L.

7.5 Calculate the pCa and pAlk from **Fig. 1** or use Eq. 8 or 9:

$$pCa = -0.4343 \times \ln(Ca_c) + 5 \quad (8)$$

$$pAlk = -0.45 \times \ln(Alk_c) + 4.8 \quad (9)$$

7.6 Calculate K , which is a function of Ionic Strength and Temperature in $^{\circ}\text{C}$, from **Fig. 2** or Eq. 10:

$$K = (0.0016 \times T + 0.5528) \times I_c^3 + (0.002T^2 - 0.0142T - 2.2695)I_c^2 + (-0.0004T^2 + 0.0266T + 2.907)I_c + (-0.0206T + 2.598) \quad (10)$$

where:

I_c = ionic strength of the concentrate, and

T = temperature in $^{\circ}\text{C}$.

7.7 Calculate saturation pH according to Eq. 11:

$$pH_{sc} = pCa_c + pAlk_c + K \quad (11)$$

7.8 Calculate the free carbon dioxide content (C) in the concentrate stream by assuming that the CO_2 concentration in the concentrate is equal to the CO_2 concentration in the feed: $C_c = C_f$. The concentration of free carbon dioxide in the feed